tion, although subsidence was greater there than in the southeast. This differential subsidence caused the southeast thinning of the nonmarine upper Muddy sediments. Muddy deposition was terminated by the rapid eastward advance of the Shell Creek or lower Mowry sea. This transgression reworked the uppermost nonmarine Muddy sediments, producing a thin, widespread sandy zone that constitutes the principal reservoir at Hilight field.

Because the lower Muddy was deposited during a southeast to northwest regression, the sandstones are progressively younger toward the northwest. However, the overlying nonmarine upper Muddy thickens northwestward, causing the underlying regressive sandstone to appear to be stratigraphically lower and, hence, older in that direction. This stratigraphic paradox has caused much confusion and difficulty in resolving Muddy stratigraphy.

GALLEY, J. E., Consultant, Kerrville, Tex.

GEOLOGIC FRAMEWORK FOR SUCCESSFUL UNDERGROUND WASTE MANAGEMENT

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GALLOWAY, W. E., Continental Oil Co., Ponca City, Okla.

DEPOSITIONAL SYSTEMS OF CISCO GROUP: THEIR RELATION TO RESERVOIR DISTRIBUTION AND PETROLEUM PRODUCTION ON EASTERN SHELF, MIDLAND BASIN

The Cisco Group is a mixed terrigenous clastic and carbonate rock stratigraphic unit deposited on the Eastern shelf, a late Paleozoic constructional platform developed on the margin of the sediment-starved Midland basin. Detailed facies mapping of the Harpersville format, a boundary-defined unit within the Cisco Group, outlines 3 depositional systems that are differentiated by gross lithologic composition and position relative to the equivalent shelf edges. They are the (1) Cisco fluvial-deltaic system, (2) Sylvester shelf-edge bank system, and (3) Sweetwater slope system. The Cisco fluvial-deltaic system is composed of dip-fed fluvial and deltaic facies and associated strike-fed interdeltaic embayment facies. The Sylvester shelf-edge bank system consists of an offlapping series of elongated, prismatic limestone banks that lie along the shelf margin. The Sweetwater slope system is composed of numerous slope wedges, or fans, which include shelf-margin, slope-trough, and distal-slope sandstone facies. The eastern shelf prograded into the Midland basin by local upbuilding through fluvial, deltaic, and shelf-edge bank deposition contemporaneous with outbuilding by slope-fan deposition.

Oil pools are found in all 3 depositional systems. Productive facies include fluvial, distributary channel, and distributary-mouth bar sandstones of the fluvial-deltaic system and distal-slope and shelf-margin sandstones of the slope system. Production is concentrated in areas where 2 broad, subparallel, structurally-related NE-SW trends intersect the mapped fluvial-deltaic lobes. The complex, lenticular geometry of these thin deltaic sandstones affords maximum opportunity for development of stratigraphic and combination traps.

GAUCHER, L. P., Consulting Engineer, Fishkill, N.Y.

ORIGIN OF PETROLEUM

As more and larger oil and natural gas deposits are found throughout the world—some in unlikely places—it becomes increasingly difficult to continue to believe that those hydrocarbons originated drop by drop through the transformation of the remains of minute animals and plants that were locked in marine sediments in relatively recent years. This "organic theory" of petroleum genesis was propounded many years ago when the number and extent of oil and gas discoveries were relatively small and when knowledge of cosmology, chemistry, and other sciences was far less sophisticated than it is today.

It is now suggested that oil and natural gas could have been formed in much larger quantities than was ever considered plausible before, through chemical reactions among components of the atmosphere that existed billions of years ago when the earth was still hot—long before there was any plant or animal life.

During the period 3–4 billion years ago, when the earth's surface was cooling from 1,000°F to about 400°F, the formation of hydrocarbons through the reaction (on catalytic surfaces) of atmospheric hydrogen and carbon monoxide seems inevitable. During that period, when the surface was still too hot for water to exist as a liquid, the earth probably was surrounded with dense clouds of hydrocarbons which literally "rained oil." This oil together with the sediments that it carried with it filled all the surface depressions that existed at the time.

Through this same kind of reaction, it is probable that several simple oxygenated compounds formed simultaneously. These acids, alcohols, aldehydes, *etc.* could well have been the source of amino acids, nucleic acids, and proteins, the precursors of cells and life itself.

The recent discovery of amino acids on a meteorite lends credence to this hypothesis and further proof may not be far off. If it can be confirmed that the clouds around the planet Venus are truly hydrocarbons, as many scientists have suggested, and if further exploration of the surface of Venus, which is reported to be at 720–885°F, discloses evidence of "oil rains" there, then the theory of petroleum genesis now proposed will be lent very strong support.

GEBELEIN, C. D., Dept. Earth and Space Sci., State Univ. New York, Stony Brook, N.Y.

BIOLOGIC CONTROL OF STROMATOLITE MICROSTRUCTURE: IMPLICATIONS FOR PRECAMBRIAN TIME-STRATIGRAPHY

Studies of Holocene stromatolitic sediments indicate that the biologic makeup of surficial blue-green algal mats controls the microstructure (features less than several centimeters in size) of stromatolites. Microstructural features include relief along a single growth surface, grain-to-grain relations within laminae, and distribution of organic matter. Recent stromatolitic sediments are basically an intertidal phenomenon. Within the intertidal zone, blue-green algal species are organized into distinct biologic communities. Each community occupies the sediment surface within a specific flooding-frequency range, and each community produces a distinctive microstructure. Recent algal communities have a wide geographic range. Similar communities and zonations may be hundreds and thousands of miles apart, but only where the areas are connected by rapidly flowing open water or wind currents (*e.g.*, areas connected by the Indian Ocean North Equatorial Current). Therefore, major stromatolite-forming algal communities do not have a worldwide distribution.

These data may be applied to the assemblages of stromatolitic microstructures which characterize 100–300 m. y. intervals in the late Proterozoic (Riphean) of the USSR. The nonrepetitive changes in microstructural assemblages through the Riphean may be understood in terms of the community organization of blue-green algae. The presence of distinctive microstructures which survived for long periods of time implies the presence of very highly biologically accommodated communities of blue-green algae, *i.e.*, of assemblages of algal species with high levels of physiologic and biochemical accommodation among species. The time range of each community and microstructure was determined by the timing of major regressions or of major reorganizations in the distribution of shallow seas. Biologically accommodated communities were broken down during these regressions or reorganizations. Microstructural assemblages had broad areal distributions within the USSR, as well as specific time ranges. Paleogeographic reconstructions of the USSR indicate that areas with similar microstructural assemblages were in open-water contact during the corresponding time period. Open-water connection accounts for the synchroneity of microstructural assemblages in the USSR, but similarity of hydrographic conditions throughout the Precambrian world ocean is improbable. Therefore, time-stratigraphic microstructural units defined in the USSR should not be used for worldwide correlation until paleogeographic relations are established firmly.

GOOLSBY, D. A., U.S. Geol. Survey, Tallahassee, Fla.

Geochemical Effects and Movement of Injected Industrial Waste in a Limestone Aquifer

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GORDON, W. A., Dept. Geol. Sci., Univ. Saskatchewan, Regina, Sask.

Physical Controls on Marine Biotic Dispersal in Jurassic

Oxygen isotope studies and biogeographic distributions indicate that the Jurassic Period was a time of only moderate latitudinal variation in temperature. Seasonal change was less well marked than at present. On land, vegetation varied geographically, but less so than at other times in earth history. Tetrapods from widely spaced land areas were quite similar. By contrast, marine invertebrates including forams, ammonoids, belemnoids, and pelecypods show distinct provincialism, and the boundaries of the marine invertebrate provinces shift through time. Physical controls that could have produced this provincialism include salinity and temperature differences in the sea, the distribution of shelf seas and deep water areas, and the geographic arrangement of sea and land, or a combination of these. Consideration of likely geographic positions of the continents during the Jurassic (assuming that they have drifted since that time), and of the likely pattern of ocean currents of the time, explains many features of the pattern of biotic dispersal. It suggests that differences in water temperature were a prime physical control on the distribution of marine Jurassic life. In particular, it indicates that the Boreal realm was not a sea area of salinity lower than average as has been suggested previously. Analogy with other Mesozoic times, and certain evidences of bipolarity in biogeographic patterns in the Jurassic, further support the view that temperature difference was a prime physical controlling factor.

GREENE, H. G., U.S. Geol. Survey, Menlo Park, Calif.

Sedimentary Features and Nearshore Processes of Arctic and Sub-Arctic Beaches

Arctic beaches show characteristic sedimentary features that readily distinguish them from beaches in more temperate zones. Along the Alaska coastline in the eastern Arctic and subarctic regions of the Bering Sea, many exotic microtopographic structures may persist throughout summer, if spring and summer weather conditions are mild enough. On prograding sections of the coast, similar features might be preserved in the stratigraphic cross section of the beach.

Microrelief features develop in spring and early summer as a result of dynamic processes associated with breakup of sea ice and thawing of kaimoo, permafrost, snow banks, and stranded blocks of ice. On the beach 2 different types of microrelief occur. Along the backshore and the upper foreshore, small streamlets and mud flows fed by melting snow and thawing permafrost produce micro-outwash and microdeltaic deposits. In the swash zone, movement of grounded sea ice by wind and waves produces ice-push ridges; melting of kaimoo ice leaves a kaimoo ridge, and melting of stranded gravel- and sand-rich brash ice creates sea-ice kettles and sea-ice sand and gravel cones. Within the nearshore areas, close to the shoreline, sea ice locally scours the bottom sediment into small randomly oriented ridges and troughs. Farther offshore, small randomly spaced hummocks of coarse sand and gravel form where ice-rafted sediment drops from grounded or stabilized melting sea ice.

GROAT, C. G., and J. H. McGOWEN, Bur. Econ. Geol., Univ. Texas, Austin, Tex.

Van Horn Sandstone, West Texas—Early Paleozoic Alluvial-Fan System

Sediment comprising the Cambrian(?) Van Horn Sandstone was derived from a highland source area of rhyolite, granite, and metamorphic and sedimentary rocks. Detritus ranging from boulders to silt was transported southward through canyons by high-gradient streams under rapid-flow and surge-flow conditions. South of the canyon mouths, the sediment was spread across the fan surface by shallower, less-confined braided streams; mud-flow deposits are absent. Three gradational facies, from north to south, are recognized in the fan deposits.

Proximal facies are deposited in the feeder canyons and near their mouths. This facies consists of massive cobble and boulder beds overlain by thinner, horizontally bedded pebble, cobble, and boulder gravels.

Mid-fan facies consist of gravels and sands. Gravel lenses are interpreted as longitudinal bars (parallel-bedded, convex-upward deposits) and channel fills (convex-downward deposits). Mid-fan sands occur as channel fills, across the tops of gravel bars, and in lows flanking them. Foreset and trough crossbeds are the dominant sedimentary structures in these sands which are interpreted as transverse bars with dunes.

Distal facies is a sand sequence in which three subfacies have been delineated: (1) braided mainstream deposits containing both foreset and trough crossbeds; (2) braided distributary deposits characterized by a relatively high content of muddy sand units, well-preserved channel cross sections, some ripple cross-laminae, and soft-sediment and injection structures; and